

Supplemental Material

CBE—Life Sciences Education

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Table 1. Framework of instructional approaches for teaching PSL in undergraduate STEM courses

Name of technique (left blank if unavailable)	Brief Description	Long Description	Disciplinary Context	Length of Intervention	In-Class or Homework	Size of Class	Level of Course	Type of College	Citations (alternate reference in parentheses)	Assessment	Assessment evidence	Cognitive Outcome (direct evidence of content learning)	Attitudinal Outcome (includes perceptions of learning)	Assessment population
	Students begin the process of reading a PSL article by watching online videos and posting questions about the article in an online forum, which later facilitates in-class discussion of the same article	<p><u>Students given:</u></p> <ul style="list-style-type: none"> Links to videos Tailored in-class content based on online discussion forum questions Guided in-class discussion questions <p><u>Students work to:</u></p> <ul style="list-style-type: none"> Watch a video on the structure of the scholarly article Take a quiz Watch additional videos if desired Read the assigned article Participate in the online-class discussion forum Participate in the in-class discussion 	Biochemistry	Single	Homework	n.d. (no data)	Advanced	4-Year	He, Y., & Masuda, H. (2015). Teaching undergraduate science majors how to read biochemistry primary literature: a flipped classroom approach. <i>Journal of Teaching and Learning With Technology</i> , 4(2), 51–57. https://doi.org/10.14434/jotlt.v4n2.13295	No				Chemistry and biology majors
	Medical journal articles which relate to course content are adapted into case studies	<p><u>Students given:</u></p> <ul style="list-style-type: none"> PSL article from a medical journal A series of open-ended questions which relate to the article <p><u>Students work to:</u></p> <ul style="list-style-type: none"> Compare and elaborate on their answers to the open-ended questions in groups Participate in an in-class discussion, with the instructor as moderator 	Biochemistry	Single	Mixed	n.d.	Intermediate	4-year	Cornely, K. (1999). Journal articles as case studies: the New England Journal of Medicine on lactose intolerance. <i>Journal of College Science Teaching</i> , 29(2), 114–119. https://my.nsta.org/resource/5973/journal-articles-as-case-studies-the-new-england-journal-of-medicine-on-lactose	No			Authors reported improved communication skills and better buy-in among students (no evidence provided).	Introductory biochemistry course
POGIL Activities	PSL articles are analyzed in student-led discussion groups	<p><u>Students given:</u></p> <ul style="list-style-type: none"> PSL article A pre-activity assignment, an in-class activity, and a post-activity skill exercise <p><u>Students work to:</u></p> <ul style="list-style-type: none"> In pre-class activity, they propose questions about the article, identify the hypothesis, and answer article-specific questions In the in-class activity, they work in groups to answer discussion questions under the guidance of the instructor In the post-activity exercise, students answer application or synthesis-level questions as individual homework exercises 	Biochemistry	Multiple	Mixed	Small	Advanced	4-year	Murray, T. A. (2013). Teaching students to read the primary literature using POGIL activities. <i>Biochemistry and Molecular Biology Education</i> , 42(2), 165–173. https://doi.org/10.1002/bmb.20765	Yes	Pre/post knowledge quiz Pre/post self-assessment of knowledge Post-module Student Assessment of Learning Gains questions www.salqsite.net	Students had higher scores on the post-test relative to pre but results not significant.	Students rated their knowledge of paper topics higher in the post-survey than in the pre. Students reported that the activity increased their learning gains in several topic areas.	Biochemistry 1 and subsequent Biochemistry 2 course
	Students are given research data which they use to write their own scientific reports	<p><u>Students given:</u></p> <ul style="list-style-type: none"> Instruction in reading PSL articles PSL article without abstract Introduction to experiments in PSL article "Pages" from a researcher's notebook <p><u>Students work to:</u></p> <ul style="list-style-type: none"> Answer questions about article which lead to them writing their own abstract Write a scientific report using provided data, as though it were their own experiment 	Biochemistry	Multiple	Mixed	Medium	Introductory	4-year	Willmott, C. J. R., Clark, R. P., & Harrison, T. M. (2003). Introducing undergraduate students to scientific reports. <i>Biochemistry Education</i> , 1(1), 1–8. https://doi.org/10.3108/beej.2003.01010010	No			Authors provide a list of positive comments from students which state that students found the activity useful and enjoyable (collection method not defined).	Level One Medical Biochemistry and Medical Genetics students
	Students complete a series of assignments which strengthen their ability to read PSL articles and interpret data figures	<p><u>Students given:</u></p> <ul style="list-style-type: none"> Instruction in how to locate PSL articles Guidance on selecting appropriate articles Questions to guide the primary literature analysis <p><u>Students work to:</u></p> <ul style="list-style-type: none"> Select a topic Complete a statement of interest Complete three primary literature analyses Make an oral presentation 	Biochemistry	Multiple	Mixed	Small	n.d.	4-Year	Spiegelberg B. D. (2014). A focused assignment encouraging deep reading in undergraduate biochemistry. <i>Biochemistry and molecular biology education</i> . 42(1), 1–5. https://doi.org/10.1002/bmb.20744	Yes	Student grades on data-analysis questions on midterms throughout the semester Post-module student evaluations of teaching	Students' marks on data-analysis midterm questions increased over the semester.	Students' comments about the module were largely positive.	Biochemistry 2 course

Program-wide primary literature intervention	Students complete a three-assignment module which has them analyze three separate PSL articles	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -PSL articles -Questions about selected figures -Quiz about a PSL article <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -Complete three assignments -Assignment 1 - they provide answers to ~3 questions regarding selected figures in a PSL article -Assignment 2 - they write summary paragraphs regarding selected figures -Participate in an instructor-guided discussion in lecture regarding the papers in Assignment 1 and 2 -Assignment 3 - read a third PSL article at home, then sit for an in-class quiz about this article 	Biochemistry and Biology	Multiple	Mixed	Large	Advanced	4-year	Sato, B. K., Kadandale, P., He, W., Murata, P. M. N., Latif, Y., & Warschauer, M. (2014). Practice makes pretty good: Assessment of primary literature reading abilities across multiple large-enrollment biology laboratory courses. <i>CBE—Life Sciences Education</i> , 13(4), 677–686. https://doi.org/10.1187/cbe.14-02-0025	Yes	Post-module grades on a paper quiz were used as the assessment. In addition, each quiz included ungraded questions for students to self-report their independent research background, the study method utilized to prepare for the paper quiz, and their confidence in their understanding of the paper as measured on a Likert scale.	Students who completed two or more modules showed greater learning gains than students who completed one module. Students who completed the module scored higher on unrelated lab assignments.	3 upper-division laboratory courses: Microbiology Lab, Molecular Biology Lab, and Biochemistry Lab. Study performed over three quarters.
	Students complete an online, interactive module which leads them from understanding the purpose and structure of PSL articles, to reading discipline-specific articles and answering associated quiz questions	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -Online modules to assist them in reading and interpreting PSL articles -Introductory module considers PSL broadly and explains how to read an article -Subject-specific modules assists students in critical evaluation of PSL articles <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -Complete the modules -Complete quiz questions integrated into the module 	Biochemistry and Biology and Chemistry	Multiple	Homework	n.d.	Introductory and Intermediate	4-year	Letchford, J., Corradi, H., & Day, T. (2017). A flexible e-learning resource promoting the critical reading of scientific papers for science undergraduates. <i>Biochemistry & Molecular Biology Education</i> , 45(6), 483–490. https://doi.org/10.1002/bmb.21072	Yes	Post-module extended questionnaire survey	Students rated the module as easy to learn from, straightforward, and helpful in understanding and reading PSL articles.	Students in the first two years of the Natural Science program
	Students receive library instruction before completing an assignment which requires them to find and summarize an article which either supports or refutes a provided hypothesis	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -Instruction in the use of library resources -Primary literature assignment which presents them with a hypothesis <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -Find and summarize an article that either supports or refutes the provided hypothesis 	Biology	Single	Homework	Small	Introductory	4-year	Shannon, S., & Winterman, B. (2012). Student comprehension of primary literature is aided by companion assignments emphasizing pattern recognition and information literacy. <i>Issues in Science and Technology Librarianship</i> , 68. https://doi.org/10.29173/istl1541	Yes	Post-module comparison of lab reports authored by students who participated in the intervention (experimental group) versus students who did not (control group)	Students in the experimental group were more likely to cite and correctly summarize a PSL article in their lab reports in comparison to the control group.	Introductory Biology laboratory course
	Students sit for a comprehensive final examination which requires them to answer questions which connect a PSL article to numerous course concepts	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -PSL article which addressed a range of topics covered over the entire course -A short-answer final examination on the PSL article <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -Read PSL article -Sit for a final examination which asks questions linking the PSL article content and course material 	Biology	Single	Homework	n.d.	Intermediate	4-year	Sulzinski, M. A. (2020). Novel primary literature-based alternative to comprehensive final examination for undergraduate virology course. <i>Biochemistry and Molecular Biology Education</i> , 49(1), 46–54. https://doi.org/10.1002/bmb.21390	Yes	Mean student grades from the PSL format final examination were compared to mean student grades from the old format final examination Student grades on final exam were compared to their grades on midterms	Students' grades on the PSL-format final examination were not statistically different from grades earned by students in the traditional-format final examination in previous years. Students' grades on the PSL-format final exam were not statistically different from their grades on traditional-format midterm exams taken earlier in the same course.	Pre-health professional and pre-graduate school students enrolled in a Virology course. Exam grades over 10 years analyzed.

Scientific Argumentation Model (SAM)	Students work through a PSL by identifying seven common arguments made by authors while justifying their experimental conclusions	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -PSL article -A sheet describing seven "moves" that play roles in forming author's argument in PSL -Instruction in the organizational and lexical criteria for identifying these moves in an article <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -Identify each of the moves in the article, which are: -Motive - they determine why research was done -Objective - they determine what the authors were trying to find out -Main conclusion - they determine the primary outcome of the study -Implication - they determine the consequences of the research -Counterargument - they identify statements which weaken or discredit the main conclusion -Refutation - they identify statements which weakn or refute the counterargument 	Biology	Single	Homework	Large	Introductory	4-year	Lacum, E. B. V., Ossevoort, M. A., & Goedhart, M. J. (2014). A teaching strategy with a focus on argumentation to improve undergraduate students' ability to read research articles. <i>CBE—Life Sciences Education</i> , 13(2), 253–264. https://doi.org/10.1187/cbe.13-06-0110	Yes	Pre/post test of article reading and interpretation assigned as homework. Students split into group A and B. Group A got Article 1 as pre-test and Article 2 as post-test. Group B got article 2 as pre-test and article 2 as post-test	Students showed significant improvement in ability to identify the 5 moves	Students reported a significant increase in their ability to read a research article, but did not show a significant increase in their perceived ability to understand the materials/methods or experimental design.	First-year life science students enrolled in a compulsory Biomedical Research course.
Write-to-Learn Assignment	Students write a brief essay about a PSL article by answering a series of guided questions	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -PSL article -Writing assignment including guiding questions -"How to Write" handout which explains how to structure an essay <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -Write a brief essay which incorporates the answers to guiding questions - requires critical evaluation of data, making connections between the paper and course concepts, and suggestions for future experiments 	Biology	Single	Homework	Large	Intermediate	4-year	Yeong, F. M. (2014). Using primary literature in an undergraduate assignment: Demonstrating connections among cellular processes. <i>Journal of Biological Education</i> , 49(1), 73–90. https://doi:10.1080/00219266.2014.8823	Yes	Pre/post knowledge survey Post-module attitudinal questions	Students showed significant increase in ability to answer paper content questions.	Students reported the module was an effective way to learn course concepts. Students said they preferred the module to traditional lecture and that it helped them understand process of scientific investigation.	Life science and bioengineering majors in a Cell Biology course.
Peer Instruction	Students work to understand experimental techniques in a PSL article, then instruct their peers to facilitate reading of PSL	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -An assigned topic about a technique in the Methods section of a PSL article <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -Research the experimental technique -Develop an information sheet about the technique -Design an in-class activity about the technique 	Biology	Single	In-class	Small	Advanced	4-year	Jacques-Fricke, B. T., Hubert, A., & Miller, S. (2009). A versatile module to improve understanding of scientific literature through peer instruction. <i>Journal of College Science Teaching</i> , 39(2), 24–32. http://www.istor.org/stable/42993334	Yes	Pre/post content knowledge assessment Pre/post self-efficacy survey related to molecular biology content knowledge and science literacy Post-module open-ended questions	Students showed increased knowledge of molecular biology techniques after completing the module.	Students reported increased confidence in reading PSL and an increase in full understanding of molecular biology techniques. Students contributed positive responses to the open-ended questions about the module.	Juniors and seniors in a capstone course of a 4-course Honors Biology series.
	Students use a matrix table to identify the five Vision and Change core concepts in a PSL article	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -An introduction to the five core concepts ("5CCs"), which are evolution; structure and function; pathways and transformation of energy and matter; information flow, exchange, and storage; systems -An overview of PSL -Instruction in a modified C.R.E.A.T.E. strategy to help them read PSL articles -A blank 5CC matrix table <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -Read article and fill in the 5CC matrix table -Work in pairs to discuss/contrast/compare their 5CC matrix tables -Participate in a whole-class discussion about the PSL article 	Biology	Single	In-class	Small	Introductory	4-year	Chatzikyriakidou, K., Manrique, C., Janelle Tacloban, M., & McCartney, M. (2021). Exploring primary scientific literature through the lens of the 5 core concepts of biology. <i>Coursesource</i> , 8. https://doi.org/10.24918/cs.2021.5	Yes	Post-module open-ended questions		Student narrative responses were positive, indicating students felt more confident reading PSL, felt the activity was useful to them as biologists, and felt they better understood the process of science.	Introductory Biology course focused on PSL.

Annotated primary scientific literature	Students are given a PSL article which has been annotated with color-coded highlights that define and identify unfamiliar terms and important parts of the article	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -An orientation in how to use the "Learning Lens", which are color-coded annotations of a PSL article -A brief overview of the importance of primary scientific literature -PSL article which has been annotated with color-coded highlights of terms and phrases which relate to seven categories ("Learning Lens"): Glossary, Previous work, Author's experiments, Results and conclusions, News and policy links. Connect to learning standards, Reference and notes <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -Read article -Click on highlighted annotations to learn more about the seven categories of the Learning Lens for that article -Answer content questions related to the article 	Biology	Single	In-class	n.d.	Introductory and Intermediate	4-year	Kararo, M., & McCartney, M. (2019). Annotated primary scientific literature: A pedagogical tool for undergraduate courses. PLOS Biology, 17(1), e3000103. https://doi.org/10.1371/journal.pbio.3000103	Yes	Post-module questionnaire requesting feedback on activity Classroom observations		Students said they liked the activity, that the activity was useful, and that it was concordant with course content	Undergraduate biology majors.
Teaching Real Data Interpretation with Models (TRIM)	Students are given data figures isolated from PSL and work to relate them to a provided model of a cellular process	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -Target model which describes cellular process -Data figures isolated from PSF, with instructor-authored legends <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -Interpret data figures in self-selected groups of 3-5 -Relate data interpretation to provided target model 	Biology	Single	In-class	Large	Advanced	4-year	Zagallo, P., Meddleton, S., & Bolger, M. S. (2016). Teaching real data interpretation with models (TRIM): Analysis of student dialogue in a large-enrollment Cell and Developmental Biology course. CBE—Life Sciences Education, 15(2), ar17. https://doi.org/10.1187/cbe.15-11-0239	Yes	Analysis of recorded data and analysis of written work. Both analyses coded student responses on a numbered scale	Students made productive use of model and were effective at interpretation of data.		Junior and senior students in a Cell & Developmental Biology course. Assessed over two years (recording) and one year (written).
	Students are given only the title of a PSL article and then write down their conjectures as to the content of the article before reading the article in its entirety	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -Title of PSL article -3 guiding questions -PSL article <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -Answer guiding questions based on PSL article title only -Read PSL article and compare article content to their answers on guiding questions 	Biology	Single	In-class	n.d.	n.d.	4-year	Liao, M. K. (2017). A simple activity to enhance the learning experience of reading primary literature. Journal of Microbiology & Biology Education, 18(1). https://doi.org/10.1128/jmbe.v18i1.1211	Yes	Post-module attitudinal survey		Student responses to surveys were generally positive, although some expressed disappointment that their answers to the guiding questions did not match the PSL article content.	Microbiology course and "more than 10 classes"
Figure Facts	Students fill in a one-page worksheet with brief summary of each PSL data figure's experimental technique and findings	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -PSL article -Figure Facts worksheet <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -Fill in the worksheet by writing a brief summary of each data figure's experimental technique and findings 	Biology	Single	Mixed	Small	Advanced	4-year	Round, J. E., & Campbell, A. M. (2013). Figure Facts: Encouraging undergraduates to take a data-centered approach to reading primary literature. CBE—Life Sciences Education, 12(1), 39–46. https://doi.org/10.1187/cbe.11-07-0057	Yes	Pre/post time-on-task assessment Three data-interpretation skills test at weeks 1, 9, & 15 of semester Mid-semester surveys and pre/post course evaluations	Students increased the amount of time they spent examining data figures and reduced the time they spent on reading text. Students showed significant improvement in ability to interpret data and analyze false conclusions (mid significant over pre, but post not significant over mid).	Mid-semester surveys showed favorable opinions of module, and pre/post course surveys showed significant drops in self-reported stress and frustration in reading primary literature articles due to module.	2 iterations of a 300-level Cellular and Molecular Neuroscience Course.
Jigsaw	Students are individually assigned separate sections of a PSL to read and interpret, then assemble into mixed groups to work through the entire article	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -A specific research question regarding a PSL article, or a specific figure or experiments to interpret <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -Assemble in mixed groups where each member has completed a separate question or figure/experiment analysis -Answer a series of questions which require the synthesis of all sections and interpretation of conclusions 	Biology	Single	Mixed	Medium	Advanced	4-year	Levine, E. (2001). Reading your way to scientific literacy. Journal of College Science Teaching, 31(2), 122–25. https://www.nsta.org/journal-college-science-teaching/journal-college-science-teaching-october-2001/reading-your-way (Fortner, R. (1999). Using cooperative learning to introduce undergraduates to professional literature. Journal of College Science Teaching, 28(4), 261-265.)	Yes	Post-module open-ended survey questions asking students what they thought of the activity and Likert-scale responses to questions which measure perceived gains		Students were likely to agree that the activity helped them improve knowledge of genetics, understand scientific process, read primary literature, increase confidence in analyzing biology concepts, and improve communication skills.	Junior-level Molecular Genetics course.

	Students use a discussion board format to help them read through a PSL article before completing a summary of the article and discussing it in class	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -Instruction in how to read PSL articles -Instruction in the experimental techniques which might appear in a PSL article -An online discussion board <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -Read the PSL article -Post questions to the discussion board -Complete a short written summary of the PSL article -Participate in an in-class discussion about the paper 	Biology	Single	Mixed	n.d.	Intermediate	4-year	Rawlings J. S. (2019). Primary literature in the undergraduate immunology curriculum: Strategies, challenges, and opportunities. <i>Frontiers in Immunology</i> , 10, 1857. https://doi.org/10.3389/fimmu.2019.01857	Yes	Post-module unprompted comments on student evaluations of teaching		Students made several positive comments about the module.	Upper-level Immunology course.
Just Figures	Students analyze a single figure from a PSL article which aligns to course content, then complete brief summaries	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -Lesson on the topic related to PSL figure -A PSL figure aligned to course content -Lecture slides or guided reading to address unfamiliar content or jargon <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -Interpret the figure -Describe experimental design, variables, controls, and main conclusion -Write one sentence summarizing results 	Biology	Single	Mixed	Small	Advanced	4-year	Massimelli, J., Denaro, K., Sato, B., Kadandale, P., & Boury, N. (2019). Just Figures: A method to introduce students to data analysis one figure at a time. <i>Journal of Microbiology & Biology Education</i> , 20(2), 20.2.29. https://doi.org/10.1128/jmbe.v20i2.1690	Yes	Pre/post CREATE survey https://doi.org/10.1187/cbe.11-03-0027 Pre/post data analysis instrument	Students scored 3 points higher on 20-point data analysis instrument after completing module, which was just as high as students who read three full papers in the class	Students reported significant increases in confidence, research comprehension, data interpretation, and thinking like a scientist	Microbial Genetics course. Three cohorts assessed.
Research Deconstruction	Students spend several class periods working through small segments of a formal research presentation by a professional scientist	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -Formal, hourlong research presentation by a scientist - 5-10 minute lessons on separate aspects of the presentation -End-of-module Q&A session with returning seminar speaker <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -Understand concepts and techniques of the research presentation -Follow the logic of the research as they better grasp the background and experiments -Ask questions of the seminar speaker at the end-of-module Q&A session 	Biology	Multiple and Half term +	In-class	Large	Introductory and Intermediate	4-year	Clark IE, Romero-Calderón R, Olson JM, Jaworski L, Lopatto D, & Banerjee U (2009) "Deconstructing" scientific research: A practical and scalable pedagogical tool to provide evidence-based science instruction. <i>PLoS Biol</i> 7(12): e1000264. https://doi.org/10.1371/journal.pbio.1000264	Yes	Post-module CURE survey https://doi.org/10.1187/cbe.04-07-0045		Students self-reported increase of many skills related to reading and analysis of PSL.	First- and second-year students in a variety of majors, over 7 quarters.
Audiocast	Students interview the author of a PSL article, then summarize the article in a 10-minute audiocast or videocast which integrates clips of the author interview	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -PSL article which they select from a predetermined list -Contact information of the author of their selected PSL article <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -Read and understand their article in small groups -Interview the author of their article -Make a 10-minute audiocast or videocast about the article which integrates audio or video clips of the interview 	Biology	Multiple	Homework	Large (but only a small number volunteered for assignment)	Intermediate	4-year	Shorbagi, S., & Ashok, A. (2016). Designing an audiocast assignment: A primary-literature-based approach that promotes student learning of cell and molecular biology through conversations with scientist authors. <i>Journal of Microbiology & Biology Education</i> , 17(3), 472-474. https://doi.org/10.1128/jmbe.v17i3.1110	Yes	Post-module attitudinal and self-efficacy survey		Students likely to report that the module was a positive experience, that it aided their learning, and that it positively influenced their attitude toward scientific research.	Cell & Molecular Biology course.

<p>Students learn to read PSL articles by completing a series of homework assignments containing short essay questions</p>	<p><u>Students given:</u> •A review of the structure and organization of the scientific literature •An explanation of the rationale and content of each section of a journal article •PSL articles •Homework assignments for each article, 10-12 short essay questions •Post-homework instruction which addresses misconceptions, common mistakes</p> <p><u>Students work to:</u> •Read article •Answer homework assignment questions</p>	<p>Biology</p>	<p>Multiple</p>	<p>Homework</p>	<p>Large</p>	<p>Introductory</p>	<p>4-year</p>	<p>Kroniris-Litowitz, J. (2013). Using primary literature to teach science literacy to introductory biology students. <i>Journal of Microbiology & Biology Education</i>, 14(1), 66–77. https://doi.org/10.1128/jmbe.v14i1.538</p>	<p>Yes</p>	<p>Pre-module analysis of homework responses</p> <p>Pre-module TIPS II test https://doi.org/10.1002/tea.3660220208</p> <p>Post-module embedded content questions in exams</p>	<p>Pre-assessments showed that while students knew the terms and concepts associated with the scientific process they did not completely understand them or were unable to apply their knowledge in a practical way to evaluate or critique research questions and the scientific literature.</p> <p>Post test was "homologous" questions on the final exam, where students scored significantly higher on 7 out of 8 questions which assessed their scientific literacy, relative to pre-assessment homework questions.</p>	<p>Two years of Introductory Biology.</p>	
<p>Students read a PSL article in two stages, with a test after each stage, and then participate in group discussion about the second test</p>	<p><u>Students given:</u> •PSL article •Conventional lecture on concepts and techniques of PSL article •Test on the first half of the PSL article •Test on the second half of the PSL article •One question from the second test after completion</p> <p><u>Students work to:</u> •Read first half of article •Sit for a test about the first half of the article •Read second half of article •Sit for a test about the second half of the article •Arrive at a consensus answer to a question from the second test in groups •Present and explain their answer to the class</p>	<p>Biology</p>	<p>Multiple</p>	<p>In-class</p>	<p>Small</p>	<p>Introductory</p>	<p>n.d.</p>	<p>Kulkarni, A., & Vartak, R. (2019). A module integrating conventional teaching and student-centered approach for critical reading of scientific literature. <i>Biochemistry and Molecular Biology Education</i>, 47(5), 581–588. https://doi.org/10.1002/bmb.21281</p>	<p>Yes</p>	<p>Written knowledge tests on days 2 and 3</p> <p>Post-module attitudinal survey completed by students.</p>	<p>Students' ability to interpret the content elements of a PSL article improved significantly</p>	<p>Most students rated the module as "excellent".</p>	<p>First-year students who have a biology course in their curriculum.</p>
<p>An intensive, multi-week roster of activities and assignments introduces first-year students to PSL</p>	<p><u>Students given:</u> •Handouts which describe how to read PSL •Definitions of confusing terms in class •Assignments containing guiding questions about the PSL article •Instruction in searching for articles by a science librarian</p> <p><u>Students work to:</u> •Read PSL article •Make a list of confusing terms as homework to bring to class •Reread PSL article to answer guiding questions •Work in groups to answer an assigned guiding questions in class •Create a poster with their groups and present to the class •Summarize the methods and results of a PSL article using a jigsaw activity •Locate articles relevant to a research question by searching databases •Complete an independent investigation by using PSL to write a research paper and give a presentation</p>	<p>Biology</p>	<p>Multiple</p>	<p>In-Class</p>	<p>Small</p>	<p>Introductory</p>	<p>4-year</p>	<p>Wenk, L., & Tronsky, L. (2011). First-year students benefit from reading primary research articles. <i>Journal of College Science Teaching</i>, 40(4), 60–67. http://www.jstor.org/stable/42992879</p>	<p>Yes</p>	<p>Pre/post coding of answers to essay questions after reading primary literature article with three levels of achievement: misunderstands (low), mentions (medium), explains (high)</p>	<p>Students' essays were scored with a significant increase in "explains" codes and significant decrease in "misunderstands" codes after the module.</p>	<p>Introductory Biology course.</p>	

Poster Session	PSL articles are read and converted into research posters by small groups, who present them to other students during an in-class poster session	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -PSL article -A research poster template <p>A 5–7-minute interview with the instructor during the in-class poster session</p> <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -Read and understand their article in small groups -Summarize the article in a poster -Present their posters during an in-class poster session 	Biology	Multiple	In-class	Small	Intermediate	4-year	Mulnix, A. B. (2003). Investigations of protein structure and function using the scientific literature: An assignment for an undergraduate Cell Physiology course. <i>Cell Biology Education</i> , 2(4), 248–255. https://doi.org/10.1187/cbe.03-06-0025	Yes	<p>Post-module Likert-scale surveys of students towards their self-assessed communication skills, ability to read research articles, relating literature to course content, and attitudes.</p> <p>Students self-reported which sections of an article (abstract, discussion, etc.) they had read in previous research articles vs. which sections they read for their research articles in this course.</p>	Students spent significantly more time reading Intro, Results, and Methods after the module in relation to papers read for other courses	Students rated most Likert-scale self-assessment questions as >3, which included questions related to perceived ability to read and interpret literature, relevance of activity, improvement in communication skills, and enjoyment of the activity.	Sophomore and junior biology and biochemistry majors in a Cell Physiology course. Two years of data collected.
Guided Literature Exploration	Students complete five assignments in a series, beginning with working to interpret heavily edited PSL articles to start and ending by analyzing unedited articles	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -PSL articles heavily edited to include only summaries of Introduction and Methods, with selected figures and tables provided -PSL articles edited to include shortened Introduction, Methods, and Results -PSL article (unedited) <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -Complete two assignments (#1-2) which require them to answer written questions about the heavily edited articles -Complete two assignments (#3-4) which require them to interpret hypotheses and draw conclusions of the edited articles -Complete one assignment (#5) where they answer questions similar to the ones posed to them in Assignments #1-4 about the unedited article 	Biology	Multiple	In-class	n.d.	Introductory	4-year	Smith, G. R. (2001). Guided literature explorations: introducing students to the primary literature. <i>Journal of College Science Teaching</i> , 30(7), 465–69. https://www.nsta.org/journal-college-science-teaching/journal-college-science-teaching-may-2001/guided-literature	Yes	<p>Post-module survey which asked students to self-assess their attitudes toward primary literature and their confidence in their abilities to interpret primary literature articles</p>	Students reported that the module helped them better understand course content, increased their confidence in reading PSL, increased their confidence in interpreting tables/graphs, and that they felt the module was a worthwhile class activity.	First course of the biology major sequence.	
	Students enrolled in a biology course are given implicit instruction in statistics by interpreting data from PSL articles	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -Graphical or table statistical data from PSL articles -PSL articles which emphasize statistics <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -Interpret PSL data -Read and discuss papers in journal club format 	Biology	Multiple	In-class	Medium	Intermediate and Advanced	4-year	Beck, C. (2018). Infusion of quantitative and statistical concepts into biology courses does not improve quantitative literacy. <i>Journal of College Science Teaching</i> , 47(5), 62–71. https://my.nsta.org/resource/?id=10.2505/4/jcst18_047_05_62	Yes	<p>Pre/post questions from the following instruments:</p> <p>Comprehensive Assessment of Outcomes in a First Statistics Course assessment (CAOS) questions https://eric.ed.gov/?id=EJ839968</p> <p>ARTIST Scale Tests of Significance https://aops3.cehd.umn.edu/artist/tests/index.html</p> <p>BioSQuaRE assessment of quantitative literacy questions https://www.macal.edu/hhmi/biosquare/</p>	Students did not show consistent overall gains in statistical and quantitative literacy, but did show gains in a number of items on the assessments	Upper-level Ecology lecture course and sophomore-level organismal biology course. Two cohorts of students assessed in each.	

	Students in a pre-major program develop science process skills early by reading and discussing PSL articles	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -Instruction on the structure of PSL articles and review articles -Instruction in searching of PSL databases <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -Compare the structure of articles -Discuss the sections of articles -Read the article and present a portion in groups 	Biology	Multiple	In-class	Large	Introductory	4-year	Coil, D., Wenderoth, M. P., Cunningham, M., & Dirks, C. (2010). Teaching the process of science: faculty perceptions and an effective methodology. <i>CBE—Life Sciences Education</i> , 9(4), 524–535. https://doi.org/10.1187/cbe.10-01-0005	Yes	Pre/post Scientific Literature Test (SLT)	Pre-module scores on SLT were 32% and post-module scores were 86%		Pre-major students enrolled in the Biology Fellows Program, intended to increase student success and retention in the biological sciences
	Students in an introductory series read related articles in groups, then present them using props and other tactile devices	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -Different PSL articles to review in teams, with all articles related to a central topic -Arts and crafts supplies, for presentation <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -Read the PSL articles -Present purpose, methods, relevant graphs, and conclusions to classmates -Use provided supplies to assist and demonstrate in the presentations 	Biology	Multiple	In-class	Small	Introductory	4-year	Goldey, E. S., Abercrombie, C. L., Ivy, T. M., Kusher, D. I., Moeller, J. F., Rayner, D. A., Smith, C. F., & Spivey, N. W. (2012). Biological inquiry: a new course and assessment plan in response to the call to transform undergraduate biology. <i>CBE—Life Sciences Education</i> , 11(4), 353–363. https://doi.org/10.1187/cbe.11-02-0017	Yes	SALG		Students self-reported significantly increased skills in reading primary literature in comparison to a control group which did not read primary literature.	Biological Inquiry first-year curriculum course
Science Seeker	Students select a concept from their textbooks then trace the evolution of that topic backwards through the literature by using citations or keyword searches to find PSL articles	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -Overview of scientific information flow from laboratory to PSL -APA style guide sheet -In-class exercises with open-ended questions <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -Complete the in-class exercises -Complete a written report to summarize gathered information -Complete a one-page summary about a data figure from students' chosen PSL article -Give an in-class presentation about the data figure 	Biology	Multiple	Introductory and Intermediate and Advanced	Small	Introductory	4-year	Petzold, J., & Montooth, K. (2010). <i>Science Seeker: A new model for teaching information literacy to entry-level biology undergraduates. Issues in Science and Technology Librarianship</i> , (63). https://doi.org/10.29173/istl2546	Yes	Pre/post test which assessed competency with Associate of College and Research Libraries (ACRL) standards Post-module student evaluations of teaching comments	Students scored higher after the module than before the module on knowledge of ACRL standards (average score of 4.6/7 post vs 3.0/7 pre, no statistical analysis).	81.25% of students recommended the module be continued in the course.	Lower-division students enrolled in Evolution & Diversity course.
Structured Primary Literature Project	Non-majors enrolled in an introductory biology course are provided with detailed instruction and rubrics to guide them in authoring and presenting an oral presentation about a PSL article	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -Instruction on identifying PSL vs. secondary scientific literature -Detailed rubrics to guide the written analysis <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -Assemble in self-selected groups to select a PSL article -Author a written analysis of the PSL article -Put together a slideshow presentation -Present the slideshow during an oral presentation 	Biology	Multiple	Mixed	Small	Non-Majors	4-year	Eslinger, M. & Kent, E. (2018). Improving scientific literacy through a structured primary literature project. <i>Bioscene</i> , 44(1), 13-27. http://www.acube.org/wp-content/uploads/2018/07/2018_1_compress.pdf	Yes	Post-module student evaluations of teaching Post-module survey of faculty survey		Students likely to agree that the instructor used effective techniques, that instructor encouraged students to work independently, and that the course improved critical thinking skills. Faculty indicated that students were better able to identify PSL and apply the scientific method as a result of the activity. Faculty agreement was > 4.5 on several 5-point Likert-scale statements, including statements which said that the activity was useful, that instructors were sufficient, and that the project was effective in improving scientific literacy and critical thinking skills.	Non-major humanities students enrolled in a one-semester Introductory Biology course.

	Students write one-page summaries of PSL articles in the style of <i>New York Times</i> articles	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -A lecture presented by an expert who provides background information on a PSL article -PSL article <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -Write a one-page summary of the paper in the style of a <i>New York Times</i> article -Discuss the PSL article in depth during a small discussion section 	Biology	Multiple	Mixed	Small	Advanced	4-year	<p>Brownell, S. E., Price, J. V., & Steinman, L. (2013). A writing-intensive course improves biology undergraduates' perception and confidence of their abilities to read scientific literature and communicate science. <i>Advances in Physiology Education</i>, 37(1), 70-79.</p> <p>https://doi.org/10.1152/advan.00138.2012</p>	Yes	<p>Post-module open-ended questions</p> <p>Pre/post surveys</p>		<p>Students reported an improved ability to write, improved communication of science, improved understanding of PSL, and felt the module was an effective way to learn course content.</p>	Upper-level Neuroimmunology course. 3 years of analysis.
Student-led Symposia	Multiple students present different PSL articles during an in-class mini research symposium	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -PSL article to be ready by a student group <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -Prepare a 5-7-minute presentation, with four students presenting four separate articles per symposium -Meet briefly with pre-symposia group members to work through last-minute questions and receive feedback -If not a presenting member of the group, write a news-article format summary of their assigned PSL article 	Biology	Multiple	Mixed	Small	Advanced	4-year	<p>Houde, A. (2000). Student symposia on primary research articles. <i>Journal of College Science Teaching</i>, 30, 184-187.</p> <p>https://www.nsta.org/journal-college-science-teaching/journal-college-science-teaching-november-2000/student-symposia</p>	Yes	<p>Pre/post surveys measuring students' confidence in reading and comprehending primary literature, in their ability to present papers, and in their understanding of research</p>		<p>Students reported significant increases in their ability to read, understand, communicate, and write about PSL.</p>	3 junior- and senior-level biology courses.
	First-year students read 5 PSL articles over two sequential courses, with increasingly challenging format for discussions	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -One essay and 5 PSL articles over two semesters -Instructor led discussions for the essay and first article -Instructor-facilitated, student-led discussions for the second article <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -Write analyses of the essay and first two PSL articles -Assemble in groups to present a third article without instructor assistance -Author written reports for the four and fifth articles presented by other groups 	Biology	Multiple	Mixed	Small	Introductory	4-year	<p>Carson, S. & Miller, E. (2013). Introducing primary scientific literature to first-year undergraduate researchers. <i>Council on Undergraduate Research</i>, 34(4), 17-22.</p> <p>https://www.cur.org/assets/1/23/Summer2013_V34.4_Carson-Miller_web.pdf</p>	Yes	<p>Post-module survey at end of second semester</p>		<p>Students reported that they had a great deal of exposure to PSL and a higher level of confidence in reading and understanding PSL after completing the module. Students also reported that the module increased their understanding of their own research and their ability to communicate science.</p>	First year, 2 semester, laboratory research course (SEA-PHAGES based curriculum with high achieving students, ~75% in honors program).
"Traditional Method"	Students read PSL articles, answer a series of questions, and participate in journal-club type class discussions	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -PSL article without abstract, title, or identifying information -Guided questions about the article before first discussion -"Big picture" questions about the article before the second discussion -Edited PSL articles for article critique exercises <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -Read and understand their article using the guided and "big picture" questions -Participate in both paper discussions -Complete article critique exercises individually 	Biology	Half term +	In-class	Small	Advanced	4-year	<p>Segura-Totten, M., & Dalman, N. E. (2013). The CREATE method does not result in greater gains in critical thinking than a more traditional method of analyzing the primary literature. <i>Journal of Microbiology & Biology Education</i>, 14(2), 166-175.</p> <p>https://doi.org/10.1128/jmbe.v14i2.506</p>	Yes	<p>Pre/post critique exercises</p> <p>Pre/post exam questions at the analysis, synthesis, and evaluation levels</p> <p>Post-module questions from SALG</p>	<p>Students' ability to critique articles improved. Students' exam scores showed a modest increase.</p>	<p>Students reported the activity to increase their interest in science and their critical thinking. Their narrative comments about the module were positive.</p>	Junior/senior level Cell Biology course. Two years of data collected.
Consider, Read, Elucidate hypotheses, Analyze and Interpret the data, and Think of the next experiment (CREATE)	Students work through a PSL article in sequential stages to read and interpret findings, then propose future experiments	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -PSL sections sequentially (no title or abstract) -Data figures isolated from PSF, with instructor-authored legends <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -Read Introduction and make a concept map -Read the Results, then cartoon their own Methods -Annotate the figures and write their own legends -Generate a hypothesis -Analyze the Results -Propose the next experiment, using cartooning -Judge the proposed experiments in student "grant panels" 	Biology	Half term +	In-class	Small	Advanced	2-year and 4-year	<p>Hoskins, S. G., Stevens, L. M., & Nehm, R. H. (2007). Selective use of the primary literature transforms the classroom into a virtual laboratory. <i>Genetics</i>, 176(3), 1381-1389.</p> <p>https://doi.org/10.1534/genetics.107.071183</p> <p>(Hoskins, S. G. (2008). Using a paradigm shift to teach neurobiology and the nature of science—A C.R.E.A.T.E.-based approach. <i>Journal of Undergraduate Neuroscience Education</i>, 6(2), A40-A52.)</p> <p>(Hoskins, S. G. (2010). "But if it's in the newspaper, doesn't that mean it's true?" Developing critical reading & analysis skills by evaluating newspaper science with CREATE. <i>The American Biology Teacher</i>, 72(7), 415-420.)</p>	Yes	<p>12 pre/post questions which required critical thinking, derived from Field Learning Assessment Guide</p> <p>http://www.flaguide.org/</p> <p>Post-module interviews to assess student attitudes</p>	<p>Students showed improvement in ability to critically analyze data and draw conclusions.</p>	<p>Students reported increased interest in becoming a scientist, increased connection to science, perceived improvement in the ability to think like a scientist, and increased understanding in how science is carried out.</p>	3 classes of juniors and seniors enrolled in a dedicated CREATE course (elective) with Genetics and Cell Biology as prerequisites.

										<p>(Hoskins, S. G., Lopatto, D., & Stevens, L. M. (2011). The C.R.E.A.T.E. approach to primary literature shifts undergraduates' self-assessed ability to read and analyze journal articles, attitudes about science, and epistemological beliefs. <i>CBE—Life Sciences Education</i>, 10(4), 368–378.)</p> <p>(Gottesman, A. J., & Hoskins, S. G. (2013). CREATE Cornerstone: Introduction to scientific thinking, a new course for STEM-interested freshmen, demystifies scientific thinking through analysis of scientific literature. <i>CBE—Life Sciences Education</i>, 12(1), 59–72.)</p> <p>(Hoskins, S. G., & Krufka, A. (2015). The CREATE strategy benefits students and is a natural fit for faculty: Analysis of scientific literature using the CREATE approach allows students to learn microbiology while involving them with the process of science. <i>Microbe</i>, 10(3), 111–112.)</p> <p>(Kenyon, K. L., Onorato, M. E., Gottesman, A. J., Hoque, J., & Hoskins, S. G. (2016). Testing CREATE at community colleges: An examination of faculty perspectives and diverse student gains. <i>CBE—Life Sciences Education</i>, 15(1), ar8.)</p> <p>(Hoskins, S. G., & Gottesman, A. J. (2018). Investigating undergraduates' perceptions of science in courses taught using the CREATE strategy. <i>Journal of Microbiology & Biology Education</i>, 19(1).)</p> <p>(Hoskins, S. G. (2019). CREATE a Revolution in undergraduates' understanding of science: Teach through close analysis of scientific literature. <i>Daedalus</i>, 148(4), 138–163.)</p> <p>(Kenyon, K. L., Cosentino, B. J., Gottesman, A. J., Onorato, M. E., Hoque, J., & Hoskins, S. G. (2019). From CREATE workshop to course implementation: Examining downstream impacts on teaching practices and student learning at 4-year institutions. <i>BioScience</i>, 69(1), 47–58.)</p> <p>(Hsu, J. L. (2020). Using primary literature on SARS-CoV-2 to promote student learning about evolution. <i>Ecology and Evolution</i>, 10(22), 12418–12422.)</p> <p>(Krufka, A., Kenyon, K., & Hoskins, S. (2020). A Single, narrowly focused CREATE primary literature module evokes gains in genetics students' self-efficacy and understanding of the research Process. <i>Journal of Microbiology & Biology Education</i>, 21(1), 100.)</p>				
Literature Circle	Students spend three full class periods in a close discussion of a single PSL article	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -PSL article -Introductory lectures about methods used in PSL articles <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -Read article and look up background information in appropriate references -Write article reviews to turn in before discussion -Spend three days discussing each PSL article - includes data interpretation, critical evaluation of conclusions, discussing impact on knowledge of field, and future directions of research 	Biology	Half term +	Mixed	Small	Advanced	4-year	<p>Janick-Buckner, D. (1997). Getting undergraduates to critically read and discuss primary literature. <i>Journal of College Science Teaching</i>, 27(1), 29–32.</p> <p>https://www.nsta.org/resources/getting-undergraduates-critically-read-and-discuss-primary-literature-cultivating</p>	Author summarizes the results of "open-ended questions" given to students at the end of the class, but no details provided	Post-module survey	Students reported increase in ability to read PSL, confidence in reading PSL, and personal satisfaction.	Advanced Cell Biology course.	

Experiential Research Project	Students complete five related and unrelated activities which help them read, interpret, and author PSL articles	<p><u>Students given:</u></p> <ul style="list-style-type: none"> •PSL articles •Instructions on five separate assignments <p><u>Students work to:</u></p> <ul style="list-style-type: none"> •Complete five PSL assignments of increasing complexity. •Journal Club about a PSL article •News article type summary of the PSL article from the journal club assignment •Disease Review Article - completed in groups and "published" in an in-house review journal •Disease Symposium Seminar - students who coauthored the disease review article present a joint 45-minute research symposium •Lab Report Written as Primary Article - student pairs who completed a wet laboratory experiment coauthor a formal manuscript designed to mimic a primary research article 	Biology	Half term +	Mixed	Small	Intermediate	4-year	<p>DebBurman, S. K. (2002). Learning how scientists work: Experiential research projects to promote cell biology learning and scientific process skills. <i>Cell Biology Education</i>, 1(4), 154–172.</p> <p>https://doi.org/10.1187/cbe.02-07-0024</p>	Yes	Pre/post survey with 13 questions related to students' perceived skills and interests		Students reported improvement of process skills and content acquisition. Student said all projects were relevant to accomplishing course goals.	Cell Biology course.
	Non-major students read PSL articles with increasing independence from the instructor, culminating in the submission of a research proposal and project	<p><u>Students given:</u></p> <ul style="list-style-type: none"> •Instruction in the distinction between PSL and secondary literature •PSL article •Definitions of unfamiliar words they bring to class <p><u>Students work to:</u></p> <ul style="list-style-type: none"> •Read paper twice as homework, underlining all unfamiliar terms •Share unfamiliar words in class with instructor •Read the paper a third time as homework •Discuss the PSL article thoroughly in class •Read subsequent articles with greater autonomy •Complete a research proposal 	Biology	Half term +	Mixed	n.d.	Non-Majors	4-year	<p>Woodhull-McNeal, A. (1989). Teaching introductory science as inquiry. <i>College Teaching</i>, 37(1), 3-7.</p> <p>https://doi.org/10.1080/87567555.1989.10532144</p>	No				Non-majors enrolled in introductory proseminar in Movement Physiology.
Online Tutorial	Non-major students complete online tutorials as homework to assist them in reading PSL	<p><u>Students given:</u></p> <ul style="list-style-type: none"> •Online tutorials about PSL articles as homework assignments •Active-learning in-class assignments related to tutorial material <p><u>Students work to:</u></p> <ul style="list-style-type: none"> •Complete tutorials and in-class assignments •Pose a question in exercise biology •Write a background paper based on secondary sources •Critique a PSL article •Write a position paper that uses PSL to argue for a position on their topic 	Biology	Half term +	Mixed	Large	Non-Majors	4-year	<p>Gillen, C. M., Vaughan, J., & Lye, B. R. (2004). An online tutorial for helping nonscience majors read primary research literature in biology. <i>Advances in Physiology Education</i>, 28(3), 95–99.</p> <p>https://doi.org/10.1152/advan.00044.2003</p>	Yes	Students asked "How challenging is the material in this class?" on mid and end-of-semester evaluations		Students stated that the module was not too challenging, and some believed it not to be challenging enough.	Non-majors enrolled in Biology of Exercise course.
Learning Community	Students participate in a three-part learning community (LC) by taking two linked major-requirement courses, then an integrative seminar course	<p><u>Students given:</u></p> <ul style="list-style-type: none"> •Enrollment in two linked major-requirement Learning Community courses which provide content knowledge •Enrollment in an integrated seminar course •Instruction in how to read PSL •Assignment which guide the students' reading of PSL •Faculty-led discussions about PSL articles <p><u>Students work to:</u></p> <ul style="list-style-type: none"> •Complete the coursework •Complete the guided reading assignments •Assemble into groups •Lead PSL discussions in class with their groups •Write and present a group research proposal 	Biology and Chemistry	Half term +	In-class	Medium	Intermediate	4-year	<p>Liotta, L. J., & Almeida, C. A. (2005, December). Organic chemistry of the cell: An interdisciplinary approach to learning with a focus on reading, analyzing, and critiquing primary literature. <i>Journal of Chemical Education</i>, 82(12), 1794.</p> <p>https://doi.org/10.1021/ed082p1794</p>	Yes	Student grades in subsequent courses	Mean and median grades for students who completed the module and subsequently enrolled in a Biochemistry I course were higher than Biochemistry I students who did not participate in the module.	Students wrote positive comments.	Sophomore level biochemistry and biology majors enrolled in 3 sequential Learning Community courses: Organic Chemistry, Cell Biology, Organic Chemistry of the Cell Integrative Seminar.

Journal Club	Students read, analyze, and present PSL articles to their instructors and peers in a journal-club format	<p><u>Students given:</u></p> <ul style="list-style-type: none"> •PSL articles, once a week, for 8 weeks •Worksheets to guide students in reading and analyzing the articles •Tutorials in how to present journal articles <p><u>Students work to:</u></p> <ul style="list-style-type: none"> •Read, analyze, and present PSL articles to their journal club 	Biology and Chemistry	Half term +	Mixed	Small	Advanced. Was a mix of undergraduate science majors, but 11/12 had previously done research.	4-year	<p>Sandefur, C. I., & Gordy, C. (2016). Undergraduate journal club as an intervention to improve student development in applying the scientific process. <i>Journal of College Science Teaching</i>, 45(4).</p> <p>https://my.nsta.org/resource/?id=10.2505/4/ics16_045_04_52</p> <p>(Glazer, Francine. (2000). <i>Journal Clubs—A successful vehicle to science literacy. Journal of College Science Teaching</i>. 29.)</p> <p>(Oxford, J. T., & Jorcyk, C. L. (2020). Students engage in primary literature in molecular biology techniques using an online journal club format. <i>Biochemistry and molecular biology education</i>. 48(6), 675–677.)</p> <p>(McDonough, V. (2012). Improving journal club: Increasing student discussion and understanding of primary literature in molecular biology through the use of dialectical notes. <i>Biochemistry and Molecular Biology Education</i>, 40(5), 330–332.)</p>	Yes	Pre/post surveys assessing student experience and confidence		Students reported increases in confidence of specific skills related to searching, analyzing, and discussing scientific literature.	Natural and physical science majors.
Grant Proposal Writing	Students learn to locate and read PSL articles as they participate in a lengthy process of researching, writing, and peer reviewing grant proposals	<p><u>Students given:</u></p> <ul style="list-style-type: none"> •Instruction in searching PSL •Formal meeting with instructor to discuss grant proposal ideas <p><u>Students work to:</u></p> <ul style="list-style-type: none"> •Practice reading PSL articles and suggesting follow-up experiments •Research a selected topic by locating and reading review articles •Write a review paper about their topic •Determine a new direction of research •Write a formal proposal •Peer review their classmates' proposals •Give oral presentations •Peer review their classmates' oral presentations 	Biology and Chemistry	Half term +	Mixed	Small	Advanced	4-year	<p>Cole, K. E., Inada, M., Smith, A. M., & Haaf, M. P. (2013). Implementing a grant proposal writing exercise in undergraduate science courses to incorporate real-world applications and critical analysis of current literature. <i>Journal of Chemical Education</i>, 90(10), 1316–1319.</p> <p>https://doi.org/10.1021/ed400130s</p>	Yes	Post-module student comments (source not defined)		Authors listed several positive student comments regarding the utility of the module.	Advanced Organic Chemistry, Endocrinology, and Ecophysiology courses.
	An interdisciplinary biophysics course is taught exclusively through the use of PSL and secondary literature, with students completing multiple assignments and presentations through the length of the course.	<p><u>Students given:</u></p> <ul style="list-style-type: none"> •Instruction in unfamiliar interdisciplinary techniques •PSL articles <p><u>Students work to:</u></p> <ul style="list-style-type: none"> •Create and present a PowerPoint presentation in pairs •Create and present a poster presentation in pairs •Complete homework assignments based on these articles •Write a literature review article 	Biology and Physics	Half term +	Mixed	Small	Advanced	4-year	<p>DeSilva, C. (2018) Using primary and secondary literature to introduce interdisciplinary science to undergraduate students. <i>Bioscene</i>, 44(2), 24-28.</p> <p>http://www.acube.org/wp-content/uploads/2019/02/Bioscene-44-2-December-2018-for-publisher.pdf</p>	Yes	Pre/post test which asked application/interpretation questions about the same PSL article Post-module survey	The mean score for application/interpretation pre-test was 51.8% and mean score for post-test was 81.8%.	Students were likely to rate their confidence, interest, ability to write a review article, and familiarity with course topics as >4 on a 5-point Likert scale.	Upperclassmen in a Biophysics course (prerequisite was completion of two semesters of biology or two semesters of physics).
Primary Literature Summary Project	Students in an introductory chemistry class complete two PSL literature reviews	<p><u>Students given:</u></p> <ul style="list-style-type: none"> •A handout describing the assignment and assessment •A discussion of project expectations in class •Instruction in locating and assessing relevant PSL articles <p><u>Students work to:</u></p> <ul style="list-style-type: none"> •Select PSL articles on a topic which interests them •Complete two written literature reviews 	Chemistry	Single	Homework	n.d.	Introductory	4-year	<p>Forest, K., & Rayne, S. (2009). Incorporating primary literature summary projects into a first-year chemistry curriculum. <i>Journal of Chemical Education</i>, 86(5), 592.</p> <p>https://doi.org/10.1021/ed086p592</p>	Yes	Post-module informal, end-of-year survey		Students were likely to agree that the module was useful, helped them appreciate chemistry, and would be of benefit to them in subsequent courses.	First-year chemistry students.

	Students complete three assignments of increasing complexity, one per course term, to develop organic chemistry research literacy	<p><u>Students given:</u></p> <ul style="list-style-type: none"> Library resource instruction Three assignments to build chemical literacy skills in sequence <p><u>Students work to:</u></p> <ul style="list-style-type: none"> Find the properties of pharmaceuticals or chemicals from five sources: popular literature, a reputable Web site, a desk reference, a PSL article, and a review article, then create an annotated bibliography Read a PSL article with title, abstract, and references removed, then write their own title, abstract, and short article summary Research a named organic chemistry reaction by locating five PSL articles that refer to the reaction, then prepare a summary of the named reaction alongside an annotated bibliography for each PSL article 	Chemistry	Single	Homework	n.d.	Intermediate	4-year	Jensen, D., Narske, R., & Ghinazzi, C. (2010). Beyond chemical literature: Developing skills for chemical research literacy. <i>Journal of Chemical Education</i> , 87(7), 700–702. https://doi.org/10.1021/ed1002674	No				Organic Chemistry course.
	Students read PSL articles and provide answers to assignment questions by using computer modeling of results	<p><u>Students given:</u></p> <ul style="list-style-type: none"> Assigned PSL article <p><u>Students work to:</u></p> <ul style="list-style-type: none"> Read PSL article Provide short answers to assigned questions Use computers to model results and for statistical analysis 	Chemistry	Single	Homework	n.d.	Intermediate	4-year	Roecker, L. (2007). Introducing students to the scientific literature. <i>Journal of Chemical Education</i> , 84(8), 1380. https://doi.org/10.1021/ed084p1380	No				Analytical Chemistry course.
	Student in analytical chemistry classes read PSL articles and complete assignments where they answer factual questions as homework and synthesis questions during in-class group discussions	<p><u>Students given:</u></p> <ul style="list-style-type: none"> PSL article An assignment containing both factual questions and open-ended, higher-order questions about the PSL article <p><u>Students work to:</u></p> <ul style="list-style-type: none"> Read the article and answer the factual questions as homework Answer and discuss the higher-order questions during class 	Chemistry	Single	Mixed	n.d.	Intermediate and Advanced	4-year	Kovarik, M. L. (2016). Use of primary literature in the undergraduate analytical class. <i>Analytical and Bioanalytical Chemistry</i> , 408(12), 3045–3049. https://doi.org/10.1007/s00216-016-9467-2	Yes	Post-module student evaluations of teaching		Students wrote narrative comments about the PSL assignments that were positive. Comments were not quoted in study.	Analytical Chemistry course.
SciFinder Scholar	Students perform a structure search for a chemical compound in SciFinder Scholar, then use the results to locate PSL articles about their compound	<p><u>Students given:</u></p> <ul style="list-style-type: none"> Instruction in the use of SciFinder Scholar (https://scifinder.cas.org/) An assigned chemical compound <p><u>Students work to:</u></p> <ul style="list-style-type: none"> Perform a structure search for their compound in SciFinder Scholar Use the SciFinder results reference list to locate one PSL article about the synthesis of their compound and one PSL article with an application of their compound Make a short presentation about their compound which includes information from the PSL articles 	Chemistry	Single	Mixed	Medium	Intermediate	4-year	Rosenstein, I. J. (2005). A literature exercise using SciFinder Scholar for the sophomore-level organic chemistry course. <i>Journal of Chemical Education</i> , 82(4), 652. https://doi.org/10.1021/ed082p652	No				Sophomore-level Organic Chemistry course.
Chemical Literature Exercises and Resources (CLEAR)	Students are introduced to chemical literature through a series of brief introductory exercises	<p><u>Students given:</u></p> <ul style="list-style-type: none"> Instruction in PSL vs secondary and tertiary sources A bibliography Specific chemical questions to research using tertiary sources <p><u>Students work to:</u></p> <ul style="list-style-type: none"> Research the chemical questions Build a bibliography on an assigned chemical topic Locate abstracts in Chemical Abstracts and provide their references (https://www.cas.org/) Select a PSL and prepare a Chemical Abstracts entry from it 	Chemistry	Single	Mixed	n.d.	Intermediate	4-year	Hostettler, J. D., & Wolfe, M. B. (1984). A brief introduction to the chemical literature with a bibliography and exercises. <i>Journal of Chemical Education</i> , 61(7), 622. https://doi.org/10.1021/ed061p622	No				Physical Chemistry Laboratory course.
	Students in an online laboratory course read an assigned PSL article and participate in a virtual symposium	<p><u>Students given:</u></p> <ul style="list-style-type: none"> Assigned PSL article <p><u>Students work to:</u></p> <ul style="list-style-type: none"> Write a summary of the assigned PSL article Answer a set of questions about the article Complete a quiz on the article Create a 15-minute presentation on article Present in a virtual symposium, Peer review other presentations Participate in a discussion board 	Chemistry	Single	Mixed	Large	Intermediate	4-year	Saar, A., McLaughlin, M., Barlow, R., Goetz, J., Adediran, S. A., & Gupta, A. (2020). Incorporating literature into an organic chemistry laboratory class: Translating lab activities online and encouraging the development of writing and presentation skills. <i>Journal of Chemical Education</i> , 97(9), 3223–3229 https://doi.org/10.1021/acs.jchemed.0c00727	Yes	Post-module survey sent via email		Students were likely to agree that the module helped them correlate course concepts with the real world, that the module was enjoyable, and that it was relevant to the course.	Mostly neuroscience and chemistry majors.

Discovering Science Information Program (DSIP)	Students in a large introductory course are introduced to information literacy with a series of librarian-authored assignments and video tutorials	<p><u>Students given:</u></p> <ul style="list-style-type: none"> •Periodic instruction on the different aspects of scholarly research during course lecture •A demonstration of a search for PSL articles using an online database •Three homework assignments created by a university librarian, each of which focused on a different primary source •Six video tutorials which addressed information literacy topics •Model solutions to the homework assignments <p><u>Students work to:</u></p> <ul style="list-style-type: none"> •Watch tutorials •Complete homework assignments •Review model solutions to the homework assignments 	Chemistry	Multiple	Homework	Large	Introductory	4-year	Locknar, A., Mitchell, R., Rankin, J., & Sadoway, D. R. (2012). Integration of information literacy components into a large first-year lecture-based chemistry course. <i>Journal of Chemical Education</i> , 89(4), 487–491. https://doi.org/10.1021/ed200252q	Yes	Pre/post library skills survey Post-module learning experience survey	Students reported statistically significant increases in confidence in their ability to use citations, search article databases, and use library web pages. Students were likely to agree that the scholarly research skills they learned were valuable skills, important for professional life, and would prove useful during their academic careers. Students also indicated that they knew how to search for primary sources and were more motivated to do so as a result of the module.	Introductory Chemistry course.
	Students read a PSL article and write a summary, evaluation, and analysis of it	<p><u>Students given:</u></p> <ul style="list-style-type: none"> •Single-page description of assignment •Partial list of journals suitable for PSL assignment •Instruction in how to find a PSL article •Draft review of papers <p><u>Students work to:</u></p> <ul style="list-style-type: none"> •Submit a PSL article, along with short summary, for approval •Research and write an analysis of the PSL article 	Chemistry	Multiple	Homework	n.d.	Intermediate	4-year	Gallagher, G. J., & Adams, D. L. (2002). Introduction to the use of primary organic chemistry literature in an honors sophomore-level organic chemistry course. <i>Journal of Chemical Education</i> , 79(11), 1368. https://doi.org/10.1021/ed079p1368	Yes	Three attitudinal surveys: early, mid, late semester	Students' opinion of their chemistry knowledge remained unchanged, but their belief that reading of PSL is important increased. Half of students stated that their science communication was improved.	Sophomore level Honors Organic Chemistry course.
	Students read PSL articles in order to rank them in their correlation to the conclusions of a secondary scientific literature article	<p><u>Students given:</u></p> <ul style="list-style-type: none"> •Instruction in the structure of PSL articles •Instruction in techniques of reading PSL articles •Secondary scientific literature article •Four PSL articles related to the secondary article <p><u>Students work to:</u></p> <ul style="list-style-type: none"> •Read secondary literature article •Identify key chemical concepts and topics in the secondary article •Rank three PSL articles related to the secondary article in order of correlation to the secondary article •Explain the hypotheses and justify ranking •Answer in-depth questions about the most related (fourth) PSL article 	Chemistry	Multiple	Homework	Medium	Introductory	4-year	Mitra, S., & Wagner, E. (2021). Introducing undergraduates to primary research literature. <i>Journal of Chemical Education</i> , 98(7), 2262–2271. https://doi.org/10.1021/acs.jchemed.0c01439	Yes	Student grades on assignments throughout the course Pre/post attitudinal survey	Grades on student assignments showed that they consistently achieved high marks in reading and interpreting PSL, even as PSL articles increased in complexity. Students indicated that they felt more confident in reading PSL at the end of the semester in comparison to the beginning of the semester.	Honors General Chemistry 1 course.
	Students complete a laboratory research report in parts, using the corresponding sections of a PSL article to guide their analysis of their own work	<p><u>Students given:</u></p> <ul style="list-style-type: none"> •Four writing assignments of increasing complexity <p><u>Students work to:</u></p> <ul style="list-style-type: none"> •Choose a PSL article •Complete four writing assignments related to their laboratory experiments, each assignment building out a section of a research report •In each assignment, use the appropriate PSL article as a model and guide for their work 	Chemistry	Multiple	Homework	n.d.	Introductory	4-year	Tilstra, L. (2001). Using journal articles to teach writing skills for laboratory reports in general chemistry. <i>Journal of Chemical Education</i> , 78(6), 762. https://doi.org/10.1021/ed078p762	No			General Chemistry Laboratory 1 course.

	Honors students are instructed in information literacy using an approach that splits their time between the library and the classroom	<p><u>Students given:</u></p> <ul style="list-style-type: none"> Instruction in searching databases during library instruction sessions An assignment which requires the use of online databases Introduction to types of sources of PSL during class sessions Instruction in how to read a PSL article A PSL article and questions as in-class assignment <p><u>Students work to:</u></p> <ul style="list-style-type: none"> Complete the online resource assignment Read the PSL article in groups Complete the in-class assignment 	Chemistry	Multiple	In-class	Medium	Introductory	4-year	Gawalt, E. S., & Adams, B. (2011). A chemical information literacy program for first-year students. <i>Journal of Chemical Education</i> , 88(4), 402–407. https://doi.org/10.1021/ed100625n	Yes	Pre/post skills test Post-module attitudinal survey	Pre-module skills test scores averaged 34% and post-module scores averaged 64%	Students were likely to rate the module as useful or very useful for helping them use library resources and learn to read PSL articles.	Chemistry and biochemistry majors enrolled in first semester of Honors General Chemistry course.
	Students use the Zotero reference manager platform to annotate PSL articles before completing a short literature summary on their topic	<p><u>Students given:</u></p> <ul style="list-style-type: none"> Instruction on the use of the Zotero reference manager platform (https://www.zotero.org/) A sample article to annotate in Zotero <p><u>Students work to:</u></p> <ul style="list-style-type: none"> Choose an article to annotate in Zotero Annotate three additional articles on the same topic Compose a bulleted outline from their annotations Complete a short literature summary with citations 	Chemistry	Multiple	Mixed	n.d.	Advanced	4-year	Kim, T. (2011). Building student proficiency with scientific literature using the Zotero reference manager platform. <i>Biochemistry and Molecular Biology Education</i> , 39(6), 412–415. https://doi.org/10.1002/bmb.20551	Yes	Post-module SALG questions which asked students to rate their perceived abilities on a 5-point Likert scale		Students reported a strong sense of their ability to write in a discipline-specific manner and an ability to work with digital resources.	Chemical Literature seminar course.
Independent Research Project	Students assemble into small groups based on overlapping interests to write a research proposal and present a poster during an in-class poster session	<p><u>Students given:</u></p> <ul style="list-style-type: none"> Instruction on how to conduct a literature search Assistance in forming groups of overlapping research interests Instruction on the assembly of a research poster Interviews by an instructor during the poster session <p><u>Students work to:</u></p> <ul style="list-style-type: none"> Write a short research proposal as individuals Form groups of 3 based on similarity of individual research proposals Submit a group research proposal Submit a formal progress report Present a poster during a class poster session Evaluate each other's posters during the class poster session 	Chemistry	Multiple	Mixed	Medium or large, depending on section size	Introductory	4-year	Tribe, L., & Cooper, E. L. (2008). Independent research projects in general chemistry classes as an introduction to peer-reviewed literature. <i>Journal of College Science Teaching</i> , 37(4), 38-42. https://my.nsta.org/resource/?id=10.2505/4/icst08_037_04_38	Yes	Post-module nonmandatory written questionnaire		Students likely to agree that the activity was a valuable learning experience, and most reported that this was their first time reading primary literature.	Science, engineering, and kinesiology majors in a General Chemistry course. 2 semesters of assessment.
Key Sentences	Students are taught to identify the key sentences in PSL articles, then work to understand how the remainder of the text relates to and supports the key sentences	<p><u>Students given:</u></p> <ul style="list-style-type: none"> Four excerpts from PSL articles Instruction in making slides <p><u>Students work to:</u></p> <ul style="list-style-type: none"> Identify the key sentence of their given excerpts Answer questions which relate the key sentence to the rest of the excerpt Group assignment which requires students to make slides using key sentences from the first five paragraphs of a PSL article 	Chemistry	Multiple	Mixed	Small	Advanced	4-Year	Bennett, N. S., & Taubman, B. F. (2013). Reading journal articles for comprehension using key sentences: An exercise for the novice research student. <i>Journal of Chemical Education</i> , 90(6), 741–744. https://doi.org/10.1021/ed200738h	Yes	Post-module attitudinal survey		Students were likely to state that the module helped them determine key sentences of PSL articles, helped them interpret the paragraphs, and helped them organize and evaluate PSL information.	Introduction to Chemical Research course.
Literature Review	Students learn to search and reach PSL by compiling a PSL review on a selected topic, then peer review other students' PSL reviews on the same topic	<p><u>Students given:</u></p> <ul style="list-style-type: none"> Instruction in the components of a PSL review Instruction in the parts of a PSL article Access to an online discussion board for questions and guidance Feedback on students' PSL review drafts Detailed format for peer review <p><u>Students work to:</u></p> <ul style="list-style-type: none"> Choose a topic Search the relevant PSL literature Submit a draft of their PSL reviews Revise their drafts and submit a final PSL review manuscript Peer review other students' PSL reviews 	Chemistry	Multiple	Mixed	Large	Introductory	4-Year	Li, T., & Liu, Y. (2022). Critical thinking through literature review in organic chemistry laboratory course. <i>Journal of Chemical Education</i> , 99(7), 2572–2578. https://doi.org/10.1021/acs.jchemed.2c00063	Yes	Post-module attitudinal survey		Students were likely to agree that the module helped improve their reading/writing ability and helped them understand connections between their coursework and real-world topics.	Organic Chemistry course for first-year medical undergraduate students.
RSS Reader	Students set up an RSS feed (news aggregator) for a PSL journal, then use articles they receive from their feed to complete homework assignments	<p><u>Students given:</u></p> <ul style="list-style-type: none"> Instruction in how to set up an RSS feed for a PSL journal Problem sets which included questions from PSL articles retrieved through the RSS reader <p><u>Students work to:</u></p> <ul style="list-style-type: none"> Set up their own RSS feeds Complete homework assignments by reading articles from RSS feeds 	Chemistry	Half term +	Homework	Number of students not specified, but authors state class was "small".	Advanced	4-year	Pence, L. E., & Pence, H. E. (2008). Accessing and managing scientific literature: Using RSS in the classroom. <i>Journal of Chemical Education</i> , 85(10), 1449. https://doi.org/10.1021/ed085p1449	No				Advanced Inorganic Chemistry course.

	Students are required to write four drafts of the Introduction to their journal-article type summaries of a laboratory research course, with the end result that they engage more and better with the PSL related to their project while fine-tuning their citations	<p><u>Students given:</u></p> <ul style="list-style-type: none"> Instruction in writing Leading questions in lecture problem sets to ease students' transition into reading an important PSL article Feedback on each of their drafts <p><u>Students work to:</u></p> <ul style="list-style-type: none"> Complete four drafts of their project introduction Improve and refine their writing in response to instructor feedback 	Chemistry	Half term +	Homework	n.d.	Intermediate	4-year	Slade, D. J., & Miller, J. S. (2017). A project provides an opportunity: Multiple drafts of an introduction require students to engage deeply with the literature. <i>Journal of Chemical Education</i> , 94(10), 1458–1463. https://doi.org/10.1021/acs.jchemed.7b00135	Yes	Pre/post count of references cited in first draft in comparison to the last draft as well as pre/post count of the number and quality of figures provided	Students cited significantly more papers in their final drafts in comparison to their first drafts and included significantly more and better-quality figures over time	Organic Chemistry 2 Laboratory. Four sequential years assessed.	
	Students develop their information literacy over two semesters, building from basic PSL article searches to using PSL to design and execute a laboratory experiment	<p><u>Students given:</u></p> <ul style="list-style-type: none"> Formal library instruction in locating PSL articles Laboratory supplies requested for their research proposals <p><u>Students work to:</u></p> <ul style="list-style-type: none"> Find, download, and read an assigned PSL article Participate in a class discussion about the article Use PSL to write a research proposal The next semester, write an experiment proposal they must test Design, develop, and test their experiment proposal in the lab Write a paper about their experiment Give an oral presentation about their experiment 	Chemistry	Half term +	Mixed	Small	Introductory	4-year	Bruehl, M., Pan, D., & Ferrer-Vinent, I. J. (2014). Demystifying the chemistry literature: Building information literacy in first-year chemistry students through student-centered learning and experiment design. <i>Journal of Chemical Education</i> , 92(1), 52–57. https://doi.org/10.1021/ed500412z	Yes	Post-module anonymous emailed surveys from three cohorts of students	Students were likely to say that literature skills were valuable and helpful for their educations, and most students cited the use of their instruction as being helpful for other coursework and research activities.	Honors General Chemistry Laboratory 1 and 2 courses over three years	
Scientific Method and Information Literacy Exercise (SMILE)	After instruction, students select, retrieve, read, analyze, and evaluate an article from a selected issue of a PSL journal	<p><u>Students given:</u></p> <ul style="list-style-type: none"> One workshop on using databases, avoiding plagiarism, and the importance of scientific literacy One workshop on how to complete a SMILE assignment by using a model paper One issue of a PSL journal <p><u>Students work to:</u></p> <ul style="list-style-type: none"> Choose and read a PSL article from the assigned journal Answer questions about how the article follows the scientific method, what the data in a chosen figure means, how the data relates to the article, and modifications that could be made to the experiment 	Chemistry	Half term +	Mixed	Large	Introductory	4-year	Porter, J. A., Wolbach, K. C., Purzycki, C. B., Bowman, L. A., Agbada, E., & Mostrom, A. M. (2010). Integration of information and scientific literacy: Promoting literacy in undergraduates. <i>CBE—Life Sciences Education</i> , 9(4), 536–542. https://doi.org/10.1187/cbe.10-01-0006	Yes	Pre/post knowledge test Post-module attitudinal survey	Students were more likely to change their incorrect answer on the pre-test to a correct answer on the post-test than vice-versa when asked to properly identify a primary PSL article, identify a figure as a graphical representation of data, and recognize the scientific method as a nonlinear process for testing hypotheses.	Students were more likely to state that using online databases to access PSL and the analysis of published data are extremely relevant to their future academic careers. Students were not more likely to agree that the scientific method is relevant to their future academic careers after completing the module.	Introductory Biology 2 course. Two cohorts of students assessed.
	Students read excerpts from PSL articles with a single accompanying figure or table, then answer factual and discussion questions relating to the text	<p><u>Students given:</u></p> <ul style="list-style-type: none"> Excerpts of PSL articles with table or figure drawn from text Brief overviews of technique highlighted in PSL excerpt Factual and interpretive/discussion-based questions about the text <p><u>Students work to:</u></p> <ul style="list-style-type: none"> Read excerpts from PSL articles Answer factual and interpretive questions about the articles Critically evaluate aspects of the data analysis Share their responses with peers 	Math	Single	In-class	Large	Introductory and Intermediate and Advanced	4-year	Rabin, L. & Nutter-Upham, K.E. (2010). Introduction of a journal excerpt activity improves undergraduate students' performance in statistics. <i>College Teaching</i> , 54, 156-160 https://doi.org/10.1080/87567555.2010.484034	Yes	Exam scores on 3 non-cumulative multiple-choice exams given throughout the course	Students who completed the module scored significantly higher on exams than students enrolled in a control section who did not complete the module	Psychology Statistics course	
	Students write a short critique of statistical analyses employed in PSL articles by using textbooks as a reference	<p><u>Students given:</u></p> <ul style="list-style-type: none"> Help identifying research fields of interest Guidance in selecting PSL articles and reference textbooks <p><u>Students work to:</u></p> <ul style="list-style-type: none"> Read through statistics textbook as a reference Critique statistical aspects of two PSL articles of their choosing Write a 3–5-page paper about their findings and critiques 	Math	Multiple	Homework	Medium	Introductory	4-year	O'Brien, T. (2005). The importance of projects in applied statistics courses. <i>Innovative Approaches to Undergraduate Mathematics Courses Beyond Calculus</i> (1st ed., Vol. 67, pp. 115-126). Mathematical Association of America. http://www.istor.org/stable/10.4169/j.ctt5hh8iv.6	No			Introductory biostatistics course	

	Students are encouraged to read PSL by completing projects which are presented to their peers	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -A PSL reading list -Guidance in choosing a research project -A venue to present their projects publicly, such as a departmental symposium <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -Read PSL articles -Submit a written report about each article, choosing either synopsis or critique -Complete projects and present them 	Math	Multiple	Homework	Small	Advanced	4-year	Rash, A. (2005) Enhancing the curriculum using reading, writing, and creative projects. Innovative Approaches to Undergraduate Mathematics Courses Beyond Calculus (1st ed., Vol. 67, pp. 13-21). . Washington, DC: Mathematical Association of America. http://www.jstor.org/stable/10.4169/j.ctt5hh8jv.4	No				Upper-division theoretical mathematics course
Meet the Researcher	First-year students read a PSL article before interviewing its author and then summarizing the main points for a non-specialist audience	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -Guidance on the project -Assigned PSL article -Introduction to PSL article author -Example summary <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -Read PSL articles and discuss in groups -Devise interview questions for article author -Interview author for 1 hour -Complete a single-page summary of the paper for a non-specialist audience 	Math	Half term +	Homework	Large	Introductory	4-year	Grindle, N., Jones, E., & Northrop, P. (2020). Harder things will stretch you further: helping first-year undergraduate students meaningfully engage with recent research papers in probability and statistics. Teaching Mathematics and Its Applications: An International Journal of the IMA, 40(1), 1–15. https://doi.org/10.1093/teamal/hraa001	Yes	Student responses to narrative open-ended question		136 of 213 student responses mentioned "learning". Of these, 73% reported acquiring new knowledge about the subject, 27% reported developing new skills and 9% said they had gained insight into attributes that are appropriate to research.	Math, statistical science, and natural science majors enrolled in a first-year introductory Probability and Statistics course
Single Story	Advanced students read several PSL articles which adhere to a single historical theme	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -Background on PSL articles through lecture -PSL articles relating to a single historical theme -In-class exercises <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -Read PSL articles -Identify unfamiliar terms -Identify points in PSL which require additional elucidation -Complete in-class exercises -Complete research project relating to the single story in groups of 2-3 	Math	Half term +	In-Class	Small	Advanced	4-year	Dietz, J. (2009). Using a "Single Story" as an Integrative Thread in an Upper-Level Mathematics Course. PRIMUS, 19(4), 311–328. https://doi.org/10.1080/10511970801945002	No				Mathematics majors enrolled in an upper-division mathematics seminar course
	First-year students answer guiding questions about a PSL article in essay form as an exam	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -PSL article -Library instruction -Guiding questions as an essay prompt and word limit <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -Complete an essay using the guiding questions 	Physics	Multiple	Homework	n.d.	Introductory	4-year	Brown, A. F. (1976). Using research papers in student assessment. Physics Education, 11(6), 421–423. https://doi.org/10.1088/0031-9120/11/6/005	No				First-year physics students
Sequential Writing Assignments	Students are given PSL writing assignments of increasing cognitive complexity	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -PSL article -A series of writing prompts <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -Write a series of assignments of increasing complexity. -Article Summary - they distill the most important information from the article -Experimental Prediction - they use the methods of a paper to predict the outcome of a similar experiment -Guided Comparison - they compare two articles and argue for what makes one paper stronger than the other -Critique - they weigh the strengths and weaknesses of a single paper -Complete the paper - the instructor provides Instructor provides part of a study, such as methods or data, and students write the rest 	n.d.	Multiple	Homework	n.d., although author said this technique is "scalable"	n.d.	4-year	Wood, Suzanne. (2020). Sequential writing assignments to critically evaluate primary scientific literature. Collected Essays on Learning and Teaching, 13, 50-56. https://doi.org/10.22329/ceit.v13i0.6013	No				

The KENSHU Method	Students work through a detailed 8-step workflow to interpret PSL, then conclude with a one-page summary and presentation	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -PSL article <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -Students complete assignments in steps. -Preparation step - they use references to define unfamiliar terms -Introduction step - they identify purpose, significance, applications, and funding sources -Experiment step - they draw diagrams of the equipment used and experiments performed -Model step - they list the symbols of the models and determine whether they are experimentally derived -Verification step - they produce their own analysis of authors' data -Results and Discussion step - they determine if the author's model correlates with the data -Conclusion step - they propose future experiments -Finally, students author a one-page summary and present to the class 	n.d.	Multiple	Mixed	n.d.	n.d.	n.d.	Drake, B. D., Acosta, G. M., & Smith, R. L. (1997). An effective technique for reading research articles - The Japanese KENSHU method. Journal of Chemical Education, 74(2), 186. https://doi.org/10.1021/ed074p186	No				Authors state the method has been used in "many courses and internships".
	Students are given instruction in reasoning fallacies and view a television show which debunks pseudoscientific claims in order to better understand the elements of a strong PSL article	<p><u>Students given:</u></p> <ul style="list-style-type: none"> -An introduction to the different types of science reports, such as experimental, observation, and case study -Instruction in reasoning fallacies -A viewing of an episode of a television series that debunks pseudoscientific claims and paranormal phenomena -Class discussion and critique of the television episode -PSL article relating to the television episode <p><u>Students work to:</u></p> <ul style="list-style-type: none"> -View the television show and discuss its arguments -Read the article and discuss it in class 	n.d.	Half term +	In-Class	n.d.	Advanced	4-year	Stover, S. (2016). Two wrongs make a right: Using pseudoscience and reasoning fallacies to complement primary literature. Journal of College Science Teaching, 45(3), 23-27. https://my.nsta.org/resource/103030/two-wrongs-make-a-right-using-pseudoscience-and-reasoning-fallacies-to-complemen	Yes	Comments from student evaluations of teaching	A list of comments from students stated that the module was interesting, that it was enjoyable, and that it helped them learn the process of science.		Junior-level students in one-credit course about reading and discussing PSL.